MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2018/2019

EOP2016 – FUNDAMENTALS OF OPTICS
(OPE)

7 MARCH 2019
9:00 – 11:00
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 8 pages with 3 Questions only.
2. Attempt **ALL** questions. Distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.

Question 1

(a) Name **two** scientists who have contributed to the area of optics and describe **one** of their major contributions.

[4 marks]

(b) An optical ray in air, is incident upon a medium at an angle of 35° with respect to the normal of the surface. The light is refracted in the medium, making an angle of 20° to the normal. If the optical wavelength in air is 450 nm, calculate

(i) the refractive index of the medium,

[2 marks]

(ii) the light velocity in the medium, and

[2 marks]

(iii)the light wavelength in the medium.

[3 marks]

(c) Calculate the critical incident angle when light strikes a glass-air boundary. The refractive index of the glass is 1.4.

[2 marks]

(d) Calculate the energy of a single photon (in Joule), for 830 nm light radiated from a laser diode.

[2 marks]

(e) State **three** optical phenomena that demonstrate the behavior of light as a wave.

[3 marks]

(f) Huygen's principle proved the law of refraction and reflection. Briefly explain the Huygen's principle.

[2 marks]

Continued...

Question 2

(a) An object is placed 7 cm in front of a convex spherical mirror of 15 cm focal length. Determine the position, the nature (real or virtual, erect or inverted), and the magnification of the image.

[7 marks]

(b) A 10 cm tall image is formed from a 3 cm tall real object by a converging lens with a focal length of 5 cm. The image is erect. Find the locations of the object and the image. Determine whether the image is real or virtual.

[7 marks]

(c) A biconvex lens with thickness of 8 cm, refractive index of 1.63 and radii of curvature of 22 cm is surrounded by air. Determine the focal lengths, the position of the principal points and the nodal points.

[6 marks]

(d) Figure Q2(d) shows refraction at a spherical surface separating media of refractive indices n and n'. The variables y and y' are positions, α, α', θ, θ' and ϕ are angles, C is center of curvature and R is radius of curvature. Derive the 2 x 2 refraction matrix.

[8 marks]

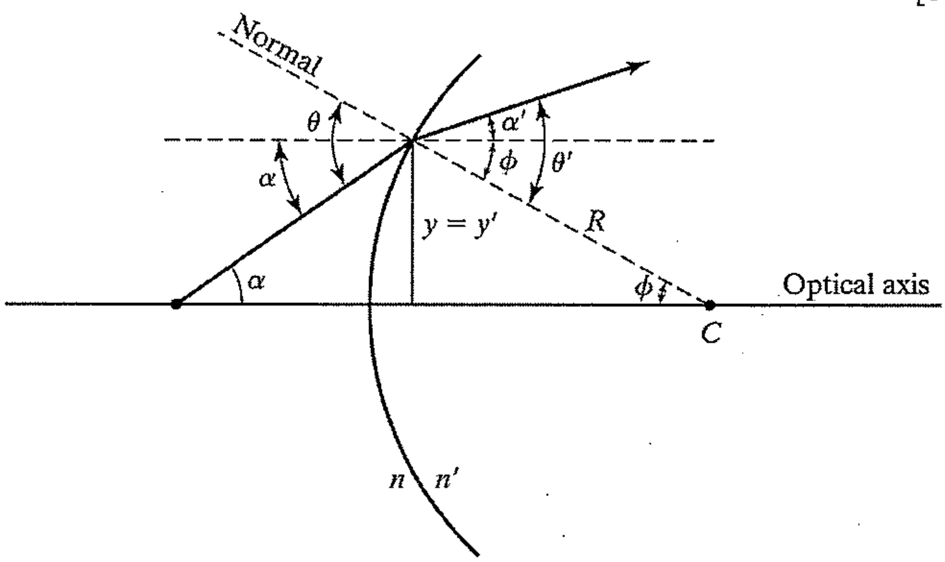


Figure Q2(d)

Continued...

(e) A harmonic wave has its electric field represented by

$$E = 15\sin\left[295x - 843t\right] \qquad V/m$$

Determine:

i. the wavelength,
ii. the frequency, and
iii. the velocity.

[6 marks]

(f) Two interfering beams with parallel electric fields are given as:

$$E_1 = 4\cos\left(ks_1 - \omega t\right) \quad (\text{kV/m})$$
$$E_2 = 7\cos\left(ks_2 - \omega t\right) \quad (\text{kV/m})$$

The beams interfere at a point P where the phase difference due to the path is $\pi/3$. Determine:

i. the irradiances of individual beams, I_1 and I_2,

[4 marks]

ii. the irradiance due to their interference, I_{12}, and

[2 marks]

iii. the visibility

[3 marks]

Continued...

Question 3

(a) At what angles will light, externally and internally reflected from a diamond-air interface, be completely linearly polarized? The refractive index of diamond is 2.42.

[4 marks]

(b) Write the normalized Jones vector for each of the following waves, and describe completely the state of polarization

i. $\vec{E} = E_0 \cos(kz - \omega t)\,\hat{x} - E_0 \cos(kz - \omega t)\,\hat{y}$

[4 marks]

ii. $\vec{E} = E_0 \sin 2\pi\left(\frac{z}{\lambda} - ft\right)\hat{x} + E_0 \sin 2\pi\left(\frac{z}{\lambda} - ft\right)\hat{y}$

[4 marks]

iii. $\vec{E} = E_0 \sin(kz - \omega t)\,\hat{x} + E_0 \sin\left(kz - \omega t - \frac{\pi}{4}\right)\hat{y}$

[5 marks]

iv. $\vec{E} = E_0 \cos(kz - \omega t)\,\hat{x} + E_0 \cos\left(kz - \omega t + \frac{\pi}{2}\right)\hat{y}$

[4 marks]

(c) Initially unpolarized light passes in turn through three linear polarizers with transmission axes at 0°, 45° and 70°, respectively, relative to the horizontal. What is the irradiance of the product light, expressed as a percentage of the unpolarized light irradiance?

[7 marks]

(d) With the aid of a diagram, describe the operating principles of an acousto-optic light beam modulator.

[6 marks]

(e) State **three** advantages of acousto-optic light beam modulators.

[3 marks]

Continued...

Appendix A

Physical Constants and Units

Constant	Symbol	Value (mks units)
Speed of light in vacuum	c	3×10^{8} m/s
Electron charge	q	1.602×10^{-19} C
Boltzmann's constant	k_B	1.38×10^{-23} J/K
Permittivity of free space	ε_0	8.8542×10^{-12} F/m
Permeability of free space	μ_0	$4\pi \times 10^{-7}$ N/A^2
Electron volt	eV	1 eV = 1.602×10^{-19} J
Planck's constant	h	6.626×10^{-34} J·s

Thick Lense Formula

$$\frac{1}{f_1} = \frac{n_L - n'}{nR_2} - \frac{n_L - n}{nR_1} - \frac{(n_L - n)(n_L - n')}{nn_L}\frac{t}{R_1R_2}$$

$$f_2 = -\frac{n'}{n}f_1$$

$$r = \frac{n_L - n'}{n_L R_2} f_1 t$$

$$s = -\frac{n_L - n}{n_L R_1} f_2 t$$

$$v = \left(1 - \frac{n'}{n} + \frac{n_L - n'}{n_L R_2} t\right) f_1$$

$$w = \left(1 - \frac{n}{n'} - \frac{n_L - n}{n_L R_1} t\right) f_2$$

Continued...

Summary of Jones Matrices

I. Linear polarizers

TA horizontal $\begin{bmatrix} 1 & 0 \\ 0 & 0 \end{bmatrix}$ TA vertical $\begin{bmatrix} 0 & 0 \\ 0 & 1 \end{bmatrix}$ TA at 45° to horizontal $\frac{1}{2}\begin{bmatrix} 1 & 1 \\ 1 & 1 \end{bmatrix}$

II. Phase retarders

General $\begin{bmatrix} e^{i\varepsilon_x} & 0 \\ 0 & e^{i\varepsilon_y} \end{bmatrix}$

QWP, SA vertical $e^{-i\pi/4}\begin{bmatrix} 1 & 0 \\ 0 & i \end{bmatrix}$ QWP, SA horizontal $e^{i\pi/4}\begin{bmatrix} 1 & 0 \\ 0 & -i \end{bmatrix}$

HWP, SA vertical $e^{-i\pi/2}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$ HWP, SA horizontal $e^{i\pi/2}\begin{bmatrix} 1 & 0 \\ 0 & -1 \end{bmatrix}$

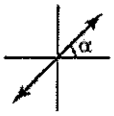
III. Rotator

Rotator $(\theta \rightarrow \theta + \beta)$ $\begin{bmatrix} \cos\beta & -\sin\beta \\ \sin\beta & \cos\beta \end{bmatrix}$

Continued...

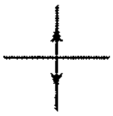
Summary of Jones Vectors

I. Linear Polarization ($\Delta\varphi = m\pi$)

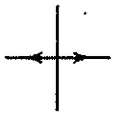
General: 

$\tilde{\mathbf{E}}_0 = \begin{bmatrix} \cos\alpha \\ \sin\alpha \end{bmatrix}$

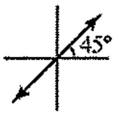
Vertical: $\tilde{\mathbf{E}}_0 = \begin{bmatrix} 0 \\ 1 \end{bmatrix}$



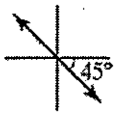
Horizontal: $\tilde{\mathbf{E}}_0 = \begin{bmatrix} 1 \\ 0 \end{bmatrix}$



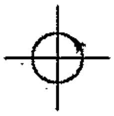
At + 45°: $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ 1 \end{bmatrix}$



At −45°: $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -1 \end{bmatrix}$

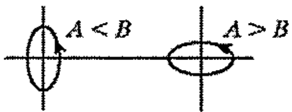


II. Circular Polarization $\left(\Delta\phi = \frac{\pi}{2}\right)$

Left:  $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ i \end{bmatrix}$

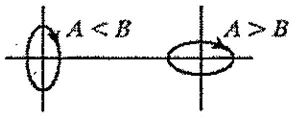
Right:  $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{2}}\begin{bmatrix} 1 \\ -i \end{bmatrix}$

III. Elliptical Polarization

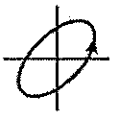
Left: 

$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2+B^2}}\begin{bmatrix} A \\ iB \end{bmatrix}$ $A > 0, B > 0$

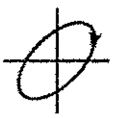
($\Delta\phi = (m + 1/2)\,\pi$)

Right: 

$\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2+B^2}}\begin{bmatrix} A \\ -iB \end{bmatrix}$ $A > 0, B > 0$

Left:  $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2+B^2+C^2}}\begin{bmatrix} A \\ B+iC \end{bmatrix}$ $A > 0, C > 0$

$\left(\Delta\phi \neq \begin{cases} m\pi \\ (m+1/2)\pi \end{cases}\right)$

Right:  $\tilde{\mathbf{E}}_0 = \frac{1}{\sqrt{A^2+B^2+C^2}}\begin{bmatrix} A \\ B-iC \end{bmatrix}$ $A > 0, C > 0$

End of paper.